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"USE OF NEW AND RENEWABLE ENERGY SOURCES IN BUILDINGS"

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Use of New and Renewable Energy Sources in Buildings

1. Shortage of energy and economic underdevelopment go hand in hand, a fact which has confronted the developing countries in an increasingly serious manner since the first oil crisis in 1973. Very few of those developing countries which have no oil reserves have shown any sign of a significant recovery in their economic growth rates during the past decade. To increase the availability of energy at affordable costs becomes, therefore, one of the prime goals of economic planning in all developing countries. Since energy consumption is quite significant in the organized (largely urban and industrial) sectors of developing countries, attention has to be focused on measures which can stretch existing sources of supply as well as on those which may enable locally available sources of energy to be effectively utilized. One such source is solar energy which is abundantly available in most of the developing countries, whose large-scale application has hitherto been hindered by economic, technological and institutional constraints.

2. The United Nations Conference on New and Renewable Sources of Energy, held in Nairobi in 1981, proposed, inter alia, measures to promote the development and utilization of new and renewable sources of energy in order to meet overall energy requirements, especially those of the developing countries. The work programme of the United Nations Centre for Human Settlements (Habitat) for 1984-85 includes a review and analysis of data on shelter development projects organized around renewable energy requirements. Activities related to this objective include preparation of guidelines for the production of national handbooks for application of passive solar heating and natural cooling design principles in developing countries. Evaluation of a number of case studies on settlements or buildings using passive design heating and cooling principles will also be undertaken.

3. The consumption of energy in buildings extends over three phases. First, the primary energy used in the production of modern building materials such as cement, steel and bricks, accounts for up to 25 per cent of the total commercial energy consumed in developing countries. Secondly, the process of construction itself requires commercial energy in the form of transportation of materials and use of equipment. Thirdly, extensive use is made of energy in the form of light, heat and working modern appliances, during the life of the building to meet the requirements of comfortable usage.

4. The building industry does not seem to have paid much attention to the adoption of materials and technologies for construction which result in conservation of energy. It is, therefore, essential to consider ways and means to utilize indigenous, local, low-energy materials, such as lime, pozzolana cement, adobe and stone. This would not only conserve energy at the building material production stage but considerably reduce energy costs during the construction phase by minimizing transportation.

5. It is known that in many developing countries a great percentage - approximately 35 per cent of total energy demand - is used in lighting, heating and cooling buildings. It is, therefore, extremely important that bioclimatic design considerations be the starting point for any building project. The present practice of designing a building from structural and cost considerations alone and then handing it over to the "climate people", namely, the lighting, heating and air-conditioning engineers, to create comfort conditions within the building often leads to the situation that electrical and mechanical systems have to compensate for design shortcomings, such as unsuitable orientation, neglected daylighting and inadequately analysed solar gains and losses, leading to much higher energy requirements than would be the case following an integrated bioclimatic design approach.

Passive Solar Heating

6. Passive solar heating designs can be most effective in temperate climates where there is sufficient sun to make them work well and winter temperatures are cold enough to make them cost-effective. In regions of mild winter climate - those with average monthly midwinter temperatures in excess of about 8°C - buildings normally have low thermal resistance and are uncomfortably cold throughout much of the winter. In these climates, passive solar heating alone, without added insulation, can markedly improve inside winter climate. In regions of severe winter climate - those with average temperatures below about 8°C - insulation must be added to achieve reasonable comfort levels.

Design Consideration

7. Passive solar technology is basically design-oriented. Much the same building materials are used as in conventional construction, but the building is put together differently to take maximum advantage of environmental conditions to enhance thermal comfort. The choice of passive solar design strategy should be based on a balance of:

(a) Life style use patterns of the building;

(b) Construction techniques and materials available; and

(c) Socio-cultural influences.

Severity of climate will determine the level of conservation and the detail design and size of elements.

8. Mass provides heat storage to carry over daytime solar gains into evening hours. There is normally ample mass in buildings of adobe, brick, concrete block or rock construction; however, a few adjustments in the use of such materials will result in the greatest heat-storage effectiveness (such as using north/south partition walls between direct gain spaces).

Types of Passive Heating

9. The three passive solar strategies of primary importance are direct gain, thermal storage wall and sunspaces.

(a) Direct gain is simply the use of windows on the equatorial side of the building. Direct-gain glazing area should be limited to no more than 10 per cent of the floor area of the building to prevent excessive temperature swings, degradation of materials within the building by ultraviolet light, and glare. In mild climates, this may be a sufficient passive solar glazing area to meet heating requirements. Equatorial-facing clerestories can also be use for direct gain and are particularly effective for daylighting.

(b) Thermal Storage walls (either Trombe walls or water walls) can be used to balance heat delivery into the building. If the building is already of massive construction, a Trombe wall can quite easily be built simply by painting or staining the outside of the wall a dark colour and glazing over it, and the incremental cost of such a modification is relatively small. It is generally not necessary or appropriate to cut thermocirculation vents through the wall. In severe winter climates, double glazing should be used, but in mild winter climates one sheet of glazing is usually sufficient. Another option is to utilize water in containers for thermal storage (a water wall), if suitable containers can be obtained at low cost. Containers should be painted a dark colour on the side facing the window but can be any colour on the room side.

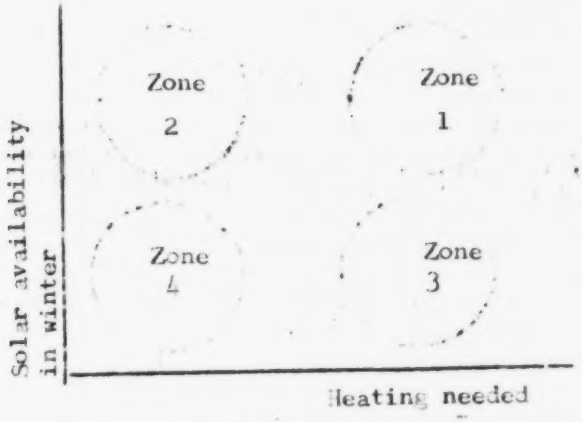
(c) An attached sunspace consists of a direct-gain room placed on the equatorial side of the building, separated from the main living or working area of the building by a wall with openings that can be closed, such as doorways or windows. The sunspace has a large area of solar glazing compared with its heat-storing mass, and, thus temperature swings will typically be large (10°-20°C). During the day, warm air is transferred from the sunspace to the rest of the building, primarily by convenction of warm air through the connecting doors and windows which are left open during the day and closed at night. The temperature in the sunspace will drop somewhat below room temperature at night but remain well above outside temperatures.

(d) An atrium within a building has proven to be a very successful passive solar design element. Properly designed, an atrium can provide passive solar winter heating, daylighting and passive summer cooling within a building, and it can, at the same time, serve as a useful living, working or public area. Such atria are most frequently included in the design of passive commercial buildings, but they have also been successfully used in several residential buildings.

Climatic Analysis for Passive Solar Heating

10. The design of passive solar heating systems depends both on the winter heating needed and the solar energy available during the heating season. The diagram below identifies four general zones according to these conditions. The heating needed increases as the outside temperature decreases, as the length of the heating season increases and as the inside temperature desired by the building occupants increases. Solar availability in winter decreases as cloudiness increases and as latitude increases.

Effectiveness of Passive Heating



The need for conservation strategies of insulation and reduced infiltration can be rank-ordered according to zone as follows:

Greatest need	Zone 3
	Zone 1
	Zone 4
Least need	Zone 2

The need for summer sun protection is usually greatest in zone 2 and least in zone 3 although this vary from case to case.

11. Characteristics of the four zones are:

Zone 1: passive heating effectiveness is greatest in zone 1, and the added investment which can be justified for double glazing, movable insulation or selective surfaces to achieve high performance is greatest.

Zone 2: Passive heating is very easy in this zone, and the size of system needed is generally modest. However, it is frequently the case that locations having a zone 2 winter climate also have a hot summer climate, and the passive heating system must be carefully designed to avoid potential adverse effects in summer. This usually means that the passive heating apertures must be carefully shaded in summer and, in extreme cases, should be completely covered to prevent diffuse solar gains.

Zone 3: Passive solar heating is difficult in climates having cold, cloudy winters. Where the heating season is very long, the energy savings are often greatest in the spring and autumn months, in which case passive heating can usually be justified. However, strategies for reducing heat loss from the passive system such as double glazing, movable insulation and selective surface, are generally necessary.

Zone 4: The incentive for passive heating is lowest in zone 4. The degree to which passive heating is taken into account in the design should usually be limited to items of low cost, for example, relocating windows to the equatorially-facing facade and using appropriate building shape and orientation.

Natural cooling systems

12. Maintaining comfort in the summer is a problem in many developing countries. Although this can be achieved with sufficient cooling of the building, the first strategy should always be to avoid cooling loads to the extent practical. In many cases, buildings become overheated inside even though outside conditions are comfortable.

13. Environmental cooling loads are caused by several factors - sunshining through windows or on the outside of roof or walls, hot outside air entering the building, or heat conducted from hot outside air to the inside. Cooling loads caused by solar gain are usually the largest problem, but these can usually be avoided through good design. Shading of the windows from direct sun is essential, especially on east and west facades, and protection from diffuse sun and reflected sun is also important. Solar loads conducted through walls and roof can be largely avoided by using white or light colours on the exterior and by insulation. Shading by vegetation is particularly effective, because the building and surrounding ground are both shaded, and the surrounding air is cooled by transpiration. The state of the art in cooling-load avoidance is well developed but unfortunately is not effectively practised in many countries.

14. Several natural sources can be used to provide cooling energy in buildings, such as the following:

(a) The night air: convective cooling;

(b) The upper atmosphere: radiant-cooling to night sky;

(c) Water evaporation: evaporative cooling;

(d) Earth cooling: storage in the sub-surface soil.

Combination of the various cooling sources is possible, e.g. initial cooling of the outdoor air by longwave radiation before using it for convective cooling.

(a) Convective cooling

15. Convective cooling implies cooling the structural mass of the building at night and utilizing the cooled mass during the following day as a sink, to absorb heat penetrating into or generated inside the building. Daytime interior ventilation is kept deliberately as low as possible to avoid bringing in hot air. In order to secure effective convective cooling, the envelope of the building should be well insulated (average value of U below about 0.67 W/m^2C) have sufficient mass "protected" by the insulated envelope and have a large surface area in relation to its mass. This method could lower the daytime inside temperature by 2-4 C. While this is a proven technique, it is necessary that the required building design characteristics are achieved.

(b) Radiant nocturnal cooling

16. Cooling of the building by the outgoing longwave radiation during the night can be achieved by either direct nocturnal cooling of the mass of the roof and subsequent protection of the upper surface by daytime external insulation or use of a specialized radiator, usually made of a metallic plate, above insulation with an air space between them. The former method can provide effective cooling in almost all climates in humid cloudy regions, but until effective and practical movable insulation becomes available, the use of this technique will be limited. The simplest design for a specialized radiator is to insulate the roof and cover the insulation with metallic sheets over an airspace of about 5 cm. Using this system, the night temperature can be dropped 4-6 C below the ambient. Any flat roof or a sloping roof with a slope up to about 30° can be transformed into a nocturnal radiator, but the experimental experience so far is only with test cells, and no actual buildings have been built using this system.

(c) Evaporative cooling

17. Cooling of buildings by water evaporation can be direct or indirect and active or passive. Inexpensive passive evaporative cooling can be provided, utilizing natural air flow by wind force through windows, by installing moist elements, such as permeable water jars or wetted matrics, in openings. It can also be provided by shaded roof ponds in direct thermal contact with the roof. Indirect evaporative cooling can be effective in regions where the summer average wet bulb temperature is below about 20 C. While research has demonstrated

the potential of shaded roof ponds to serve as a cooling system in arid regions, no field experience is available.

(d) Earth cooling

18. It is possible to lower the earth temperature, within a confined area, well below its "natural" level, by eliminating its heating by the sun while encouraging evaporation from the earth surface. This can be done by raising the building off the ground and supporting evaporation from the surface by irrigation or feeding rains below the buildings. Alternatively, the soil can be covered with a layer of gravel, at least 10 cm. thick and, in regions with dry summers, irrigating it. Using this technique, the difference between the outdoor maximum temperature and the cooled earth temperature can be up to 15 C (in mid-summer), providing a good heat sink for the building. In this area, too, no research on the performance of practical building systems seems to have been done.

19. In view of the fact that very large populations in the developing areas in hot dry regions and in hot humid conditions have to suffer serious discomfort for considerable periods of the year, the search for low-cost cooling is a key area where new basic concepts and designs are badly needed. As materials are critical to effective progress, promoting use of local materials, both for passive solar heating and natural cooling systems, will require considerable research and development effort. Research is needed into glazing materials, insulating materials using agricultural and industrial residues and wastes, cost-effective selective coating materials and their associated manufacturing processes, corrosion and weather resistance of materials, and reliability of components.

20. In order to carry out the above research tasks, and developmental minimal meteorological data should become available. Special manuals should be disseminated to guide the preparation of national and regional bioclimatic design handbooks. A systematic programme for the construction of demonstration buildings should be undertaken as an important step in the dissemination of information from one part of the world to another.